MUTUAL RELATION OF LEAKAGE AND EMISSION CURRENTS IN THE Al-Al2O3-Al SYSTEM

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In the present paper the analysis of VA characteristics of the leakage current determined experimentally for the Al-Al2O3-Al system is discussed. It is shown that the total leakage current is given by a sum of several local currents from the single places of the dielectric given by various mechanisms acting simultaneously. The tunnel component of the leakage current passes through a part of the dielectric area only. This current component obeys the same regularities holding for the case of emission current of electrons into vacuum. Comparison of the values of applied field intensity obtained for this tunnel component leakage current with the values corresponding to the Fowler-Nordheim equation suggests the assumption of a nonuniform potential distribution in the dielectric, i.e. the existence of a region where the potential drop agrees with the theoretical values and the region of a lower potential drop. Further, the influence of the position of potential barrier and the transmission probability over the top electrode on the emission VA characteristics is shown.

1. INTRODUCTION

In the works published to date the emission current of electrons emitted through the MIM system into vacuum is assumed to be in principle a part of the leakage current between the metal electrodes and the ratio of both mentioned currents is specified as the transfer coefficient $\alpha$. The question, whether both currents comply with the same mechanism, even though the expression of their VA characteristics may be totally different, e.g. [1], has not been answered yet.

Namely, the different shapes of VA characteristics the leakage and emission currents have not been determined not only for the system with anomalous VA characteristic of the leakage current, but also for those systems with a normal monotonous VA characteristic. Unsolved remains still the question of determining the applied field intensity needed for formation of a given tunnel current component of electrons. On increasing the dielectric thickness the applied field intensity necessary to maintain the current of required magnitude decreases, which leads to the assumption of an uneven field distribution in the dielectric layer.

The aim of this work has been to show that the leakage current is usually composed of at least two independent components, from which only one may cause the emission of electrons into vacuum. At the same time the corresponding shapes of VA characteristics of emission currents together with the assumption on the shape of a nonuniform potential distribution in the dielectric layer are demonstrated.

Taking into account the electron conduction only, five mechanisms would appear to be in principle possible for electrical current conduction through the thin oxide

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Mutual relation of leakage and emission currents...

If the conduction is barrier-processes limited, then the electron tunneling through the potential barrier at the interface, or the Schottky over-barrier emission of electrons take place. In case the volume processes are the determining mechanisms for the electron conduction, then the Poole-Frenkel effect, the space-charge-limited and ohmic currents may be applied. Usually, the current for the above-mentioned system is assumed to be given by one mechanism only.

Fig. 1. Dependence of maximum (dot-and-dashed lines) and end points (dashed lines) of the internal electron energy distribution $N(E_x) \, dE_x = P(E_x) \cdot S(z) \cdot dE_x$ on the applied field intensity $F$ for three various thicknesses of the dielectric. (Full lines represent the position of the top of the upper electrode potential barrier). $W_F$ is the Fermi energy of the basic metal.

SODOMKA [4] has determined at measurements of the energy distribution of emitted electrons that the emitted electrons correspond to the tunnel component of the current only, although the VA characteristic of the leakage current exhibited a linear dependence in $\ln i_\text{L} \sim \sqrt{U}$ coordinates. The measured distribution using the results of the quoted work may be expressed by the relation

$$N(E_x) \, dE_x = \gamma \, P(E_x) \cdot S(z) \cdot D(E_x) \cdot dE_x$$

where $\gamma$ is the coefficient including the electron loss at transmission through the upper metal electrode, $P(E_x)$ is the number of electrons emitted from the basic metal into the dielectric in the $x$-direction per unit time and unit area of the potential barrier.